

# **NPP/NPOESS Joint Government SSPR Contractor Calibration and Validation Program: System Perspective, Cooperative Strategy, and Path to NPP**

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## **ABSTRACT**

The overall objective of the NPOESS Preparatory Project (NPP) / National Polar-Orbiting Operational Environmental Satellite System (NPOESS) Joint Government Shared System Performance Responsibility (SSPR) Contractor Cal Val Program is to ensure the environmental data products meet the system specification, and satisfy the users and scientific community. Work spans all program phases, from pre-launch sensor characterization and data product verification to on-orbit calibration verification/data product validation and long-term data product quality monitoring/maintenance. A cooperative approach is in place to leverage expertise throughout the program, customer, user, and scientific community. Draft Calibration and Validation Plans are in development and NPP pre-launch activities are underway. This paper provides a NPP/NPOESS Cal Val Program system perspective, describes the cooperative strategy, and summarizes progress and planned activities to ensure a successful NPP mission

**Keywords:** NPOESS, NPP, environmental satellite, data products, operations, weather, calibration, validation, verification

## **1. INTRODUCTION**

The purpose of the National Polar-orbiting Operational Environmental Satellite System (NPOESS) is to collect global multi-spectral radiometric and other specialized meteorological, oceanographic, and solar-geophysical data and to disseminate these data to the system's central and field users deployed worldwide. These data are processed and delivered to the users in the form of Raw Data Records (RDRs), Sensor Data Records (SDRs), Temperature Data Records (TDRs), and Environmental Data Records (EDRs). The fundamental acquisition approach employed by NPOESS is based on the requirements for the NPOESS EDRs as specified in the NPOESS System Specification [1].

The primary objectives of the NPOESS Calibration Validation (Cal Val) program are to ensure the mission data products meet Appendix D of the system specification and satisfy the users. Appendix D defines the data products and their performance and timeliness requirements. The users consist of the NOAA National Environmental Satellite, Data, and Information Service (NESDIS), Air Force Weather Agency (AFWA), Fleet Numerical Meteorology and Oceanography

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Center (FNMOC), and Naval Oceanographic Office (NAVOCEANO). The correct interpretation of NPOESS data products requires the ability to discriminate between any change in the system (e.g., on-orbit changes in the instrumentation, orbit variations, ground data processing, etc.) and actual changes in the physical environment observed by the system. It is necessary to carry out a comprehensive calibration and validation program over the complete course of the NPOESS mission life cycle to achieve this goal. The Cal/Val program encompasses a broad range of activities pre-launch and post-launch of the NPOESS satellites. It also involves inter-sensor and inter-satellite comparisons. The calibration of the NPOESS instruments is with respect to a set of recognized physical standards and processes. Furthermore, each instrument is characterized at the subsystem and system levels to support the pre-launch calibration, cross-calibration and post-launch calibration and validation activities.

A comprehensive Cal Val program is needed to demonstrate that NPOESS is meeting its overall mission requirements. The critical role played by Cal Val has also been emphasized by several national and international organizations involved with environmental remote sensing [2-4]. The SSM/I Cal Val provides an example where large errors with geolocation and EDR retrieval algorithms were discovered during initial post-launch data analyses, which resulted in a considerable on-orbit Cal/Val and algorithm redevelopment phase [5]. The modified sensor and algorithm parameter were applied to the data processing systems at AFWA and FNMOC in stages from 1989–1991 [6]. The inter-comparison of EDRs observed by different instruments over a long period of time; such as the measurement of total solar irradiance over 2 decades, is another example of the importance and utility of Cal Val.

The NPOESS mission converges the missions of the DoD DMSP and the DOC NOAA POES missions, delivering environmental data products for weather forecasting and operational support to both agencies. In addition NPOESS will provide continuity to the NASA science mission for environmental remote sensing and climate monitoring, following the EOS satellites. The NPOESS Preparatory Project (NPP) launch is scheduled for late 2006, and NPOESS satellites C1 through C5 span 2009 to 2017 launch dates.

The NPOESS Cal Val program intensive development began August 2002, when Northrop Grumman Space Technology (NGST) was selected as the NPOESS SSPR contractor. A joint Government SSPR contractor NPOESS Cal Val Working Group was formed February 2003 to coordinate the planning and support the execution of the NPOESS Cal Val Program. Participants include the SSPR contractor, customer, and science and user communities. A cooperative philosophy and proactive approach is helping ensure that the appropriate NPP pre-launch activities are conducted and the NPOESS system fully supports required NPP and NPOESS post launch and long term monitoring activities.

## **2. PROGRAM PARTICIPATION AND APPROACH**

The NPOESS Cal Val Program participants include the SSPR contractor, customer, science community, and user community, see Figure 1. There are three major categories of effort, exploration and exploitation activities, performance advisory activities, and development activities.

NPOESS internal government studies, the NASA NPP science team, and a joint NPOESS P3I effort support exploration and exploitation activities. Advisory activities are supported by the IPO sponsored NPOESS Operational Algorithm Team (NOAT), the NGST sponsored Science Advisory Team (SAT), and the jointly coordinated NPOESS Customer Forum. Development activities are supported by integrated product teams (IPT's) within the IPO/NASA and NGST. The NPOESS Cal Val Working group cuts across all activities categories and includes SSPR contractor and government participation. The SSPR contractor Cal Val team includes participation from NGST and Raytheon ITSS.

The NPOESS Cal Val Program is divided into pre-launch, post launch, and long term monitoring phases, see Figure 2. The NPP post launch phases extends from launch to launch + 20 months. Long term monitoring starts during the post launch phase, and extends through the operational life of the program. Within the SSPR contractor, various integrated product teams (IPT) conduct the key activities, see Figure 2.



For the pre-launch phase, the sensor is characterized and calibrated under the direction of the Payload (PL) IPT. The characteristics of the sensor are used to develop the sensor data record (SDR) algorithm. The SDR algorithm translates the raw information collected at the sensor or raw data record (RDR) into calibrated and geo-located radiances (i.e. SDR). The sensor characterization and test program verifies the SDR algorithms are adequate and produces preliminary SDR algorithm input parameters. Sensor vendors are responsible for delivering the sensor and the SDR algorithms to NGST. The NPOESS environmental data record (EDR) algorithms build on those from legacy programs and incorporate improvements from EOS. These algorithms translate the calibrated geo-located radiances into environmental data products. The science algorithms are verified by the System Engineering (SE) IPT, converted to operational algorithms by the Interface Data Processing System (IDPS) IPT, and then verified as operational algorithms by the System Test and Evaluation (ST&E) IPT. EDR performance is verified by inserting synthetic or proxy SDR test data into the EDR algorithm. Synthetic test data is generated by producing geophysical scenes (i.e. comparison or truth source) and corresponding geo-located and calibrated radiances. Proxy data is generated by converting heritage sensor SDR data into NPOESS sensor SDR data. The heritage program EDR is used as comparison data.

For the post launch phase, the sensors are activated and performance verified, and SDR / EDR's are validated by the Operations & Support (O&S) IPT and ST&E IPT. Initial checks of the on-board calibration subsystem is performed and compared to pre-launch measurements. Sensor performance is qualitatively assessed over a range of scenes to determine if there are any major problems that require resolution. Sensor models are updated, and test data scenes are reprocessed to confirm EDR performance. SDR's are calibrated and validated by comparing sensor radiometric measurements with independent sources of measurement, such as aircraft under flights, inter-satellite comparisons, vicarious calibration using characterized ground sites and specific calibration campaigns. EDR's are validated by comparing NPOESS EDR's produced by the IDPS with independent truth or comparison data.

For the long term monitoring phase, all NPOESS sensors and data products are continuously monitored for data quality within the IDPS by the O&S IPT. Once the nominal post launch intensive Cal Val period has ended, the program will transition to normal operations and long term monitoring. Additional Cal Val activities may be required to support problem resolution or long term climate monitoring activities.

A Joint SSPR Contractor NPOESS Cal Val Working Group was formed February 2003 to coordinate the planning and support the execution of the Cal Val program, for the 25-year duration of the NPOESS program. The basic structure of the working group is shown in Figure 3. Working group participation includes the SSPR contractor, customer, science community, and user community. Working group focus, general membership and meeting agenda is coordinated by the CVWG Executive Board, shown in Figure 3, and morphs as appropriate. The Executive Board has SSPR contractor and government representatives, in areas of sensors, algorithms, and science.

During the NPP era, the NPOESS Cal Val Working Group is structured as shown in Figure 4. There are individual sensor focused groups to ensure adequate sensor data records (SDR's), and science focused groups to validate EDR's in the sounder, ozone, atmospheric, cloud, land, and ocean product disciplines. Each group has government and SSPR contractor participation and is responsible for specific algorithms and where applicable, related deliverable products.

The NPOESS Cal Val Working Group held an inaugural meeting on June 2003, to bring together leaders from the variety of institutions to discuss the NPOESS Cal Val Program strategy and help define the best way to cooperate over the life of the program. During Fall 2003, the NPOESS Cal Val Working Group focused on pre-launch sensor characterization and calibration. Individual meetings were held at each of the sensor vendors to ensure complete understanding of what characterization and calibration is planned, discuss NIST involvement, and identify challenges that need to be worked. In April 2004, the emphasis shifted to the post launch phase, with the primary objective of defining the details for SDR and EDR validation. This included identifying necessary support and truth or comparison data. SDR groups and the sounder and ozone product groups met. A follow up NPOESS Cal Val Working Group meeting is scheduled for July 2004 and September 2004 to discuss land, atmosphere, ocean, and cloud validation. Future NPOESS Cal Val Working Group meetings will focus on SSPR contract post launch milestone exit success criteria, long term monitoring, and rehearsal preparation.

# NPOESS Cal Val Working Group

CVWG Executive Board			
SSPR Contractors		Government	
Cal/Val Lead	Brian Lottman	IPO NPOESS/NPP Cal/Val Lead	Karen St. Germain
Cal/Val Scientist	Mike Mussetto, Scott Shipley	NASA NPP Cal/Val Lead	Bruce Guenther
Payload Performance Lead	Jim McCarthy	IPO Program Scientist	Steve Mango
Algorithm Performance Lead	Pam Emch	NASA NPP Deputy Project Scientist	Jim Butler

CVWG General Membership	
SSPR Contractors	Government
Membership & Structure Varies Depending on Timeframe within NPOESS Program	

Figure 3 Here – NPOESS Cal Val Working Group Basic Structure

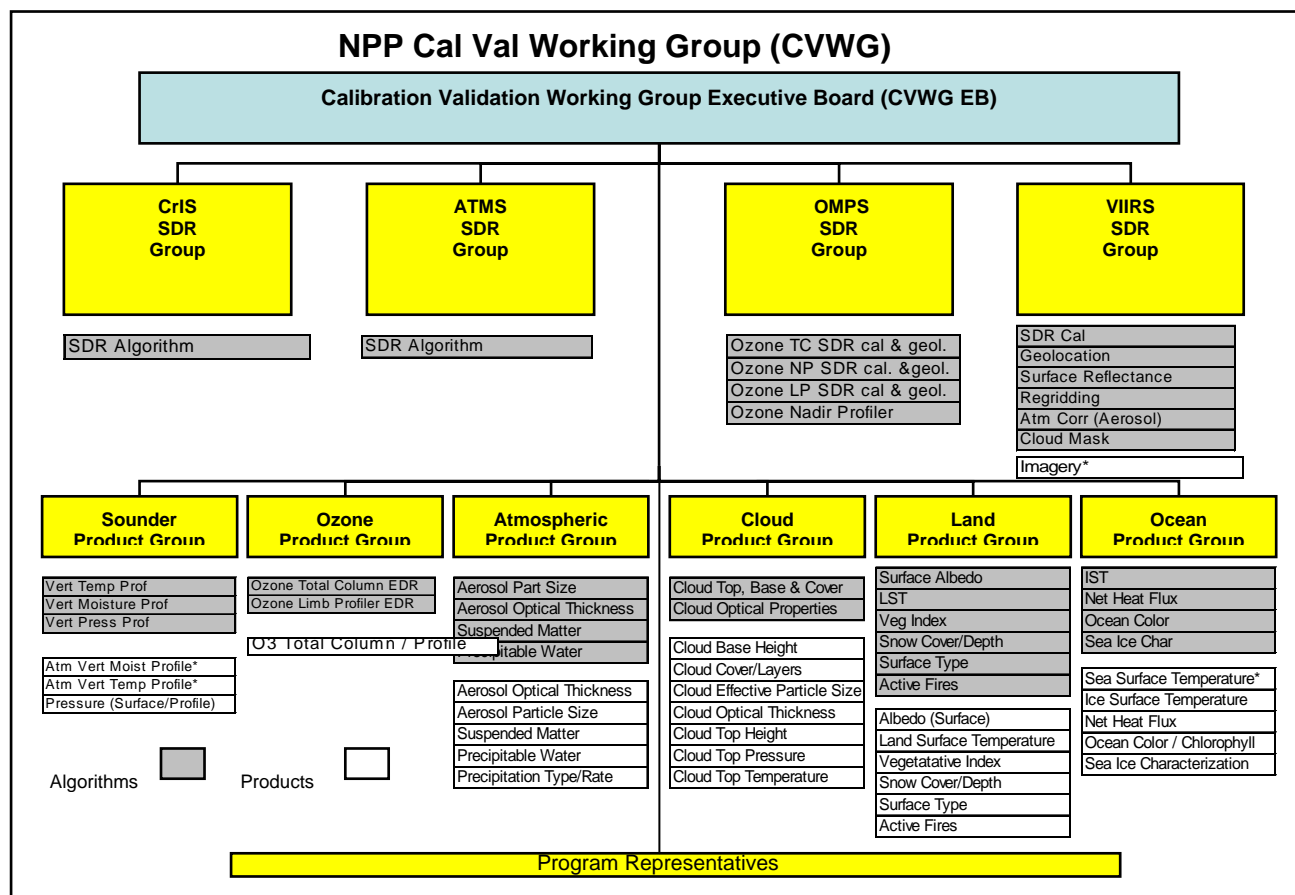


Figure 4 – NPOESS Cal Val Working Group Structure for NPP

### **3. NPP/NPOESS CAL VAL PLANS**

The SSPR contractor NPOESS Cal Val Program strategy is to produce NPOESS sensor specific Cal Val plans (ten volumes) based on heritage science and scientists. These plans describe best practices for all phases of Cal Val across the life of the program. Platform specific plans (NPP, NPOESS C1, NPOESS C2) are developed by a Joint Government SSPR contractor team that incorporate the details of the given platform, and leverage the best practices established in the sensor specific plans.

The NPOESS Cal Val program planning effort has been underway since 2001. The IPO/NASA government team developed a draft NPP Calibration and Product Validation Plan released in December 2001. During the SSPR contractor proposal effort, draft sensor specific plans were developed for the VIIRS, CrIS/ATMS and CMIS sensors. Since SSPR contract award August 2002, the SSPR contractor team in conjunction with the science community developed / updated sensor specific Cal Val plans for nine sensors; VIIRS, CrIS/ATMS, OMPS, CMIS, ALT, TSIS, ERBS, SESS, and GPSOS. These plans were developed in two stages that included program and community reviews. The plans were put under configuration control as part of the NPP Mission Critical Design Review (MCDR), November 2003. The plan development schedule is in concert with the NPOESS system design cycle to ensure the system architecture will fully support the needs of the Cal Val team. The sensor specific Cal Val plans are updated every six months until they become formal deliverables at NPOESS CDR, April 2006. The Joint Government SSPR contractor NPP Cal Val plan is under development and a mature draft version will be released October 2004, two years prior to NPP launch.

### **4. NPP CALIBRATION VALIDATION PROGRAM ROADMAP**

As previously stated, within the SSPR contractor, various IPT's conduct Cal Val tasks as part of their normal scope of work, see Figure 2. The SSPR Contractor Cal Val team serves as the corporate memory for pre-launch activities, and is responsible for building the supporting test infrastructure and conducting the post launch and long term monitoring portions of the NPOESS Cal Val Program. The SSPR Contractor Cal Val team recognizes the importance of adequate pre-launch activities, and thus works with all associated SE, PL, & IDPS IPT's to enhance and support those efforts. The detailed tasks for the SSPR contractor Cal Val team are scheduled for intervals of six months. The SSPR contractor team restructures as necessary to best support those needs within each interval.

A NPP Cal Val Program roadmap with major program milestones and key activities is shown in Figure 5. NPP launch is scheduled for October 2006. The following are the key pre-launch milestones; NPP Ground Readiness Review (NPP GRR) March 2006, NASA's NPP On-Orbit Test Plans and Procedures Review (NPP TPRR) May 2006, and NPP On-Orbit Data Processing Test Readiness Review (NPP TRR) September 2006. For NPP GRR, Site Acceptance Tests are conducted at each Central (NESDIS, AFWA) to demonstrate ground readiness. For NASA's NPP TPRR, the SSPR contractor will provide on-orbit test plans and procedures for VIIRS, CrIS, OMPS. NPP TRR involves reviewing NPP Ground Segments (test, plans, procedures, and logistics) as well as sensor readiness to acquire, process, and distribute environmental data. The following are the key post-launch milestones; NPP On-Orbit Data Processing Capability Verification Review (NPP VR) May 2007, and Final NPP On-Orbit Data Processing Capability Review (NPP FVR) June 2008. The purpose for the NPP VR is to verify NPOESS system processing of initial NPP data. The purpose of NPP FVR is final verification of NPOESS system processing of NPP data.

Key activities are now underway to support pre-launch, post launch, and long term monitoring phases of the Cal Val program.

For pre-launch activities, all NPP sensors vendors are conducting sensor characterization and calibration activities, and results are supporting science algorithm verification efforts. The NPOESS Cal Val Working Group focus for Fall 2003 was ensuring sensor characterization and calibration is sufficient for Cal Val. NGST will complete verification on the majority of the science algorithms and complete delivery of those algorithms to IDPS for operational code conversion by December 2004. Operational algorithm verification is also underway and will conclude with a system level test starting in March 2006.

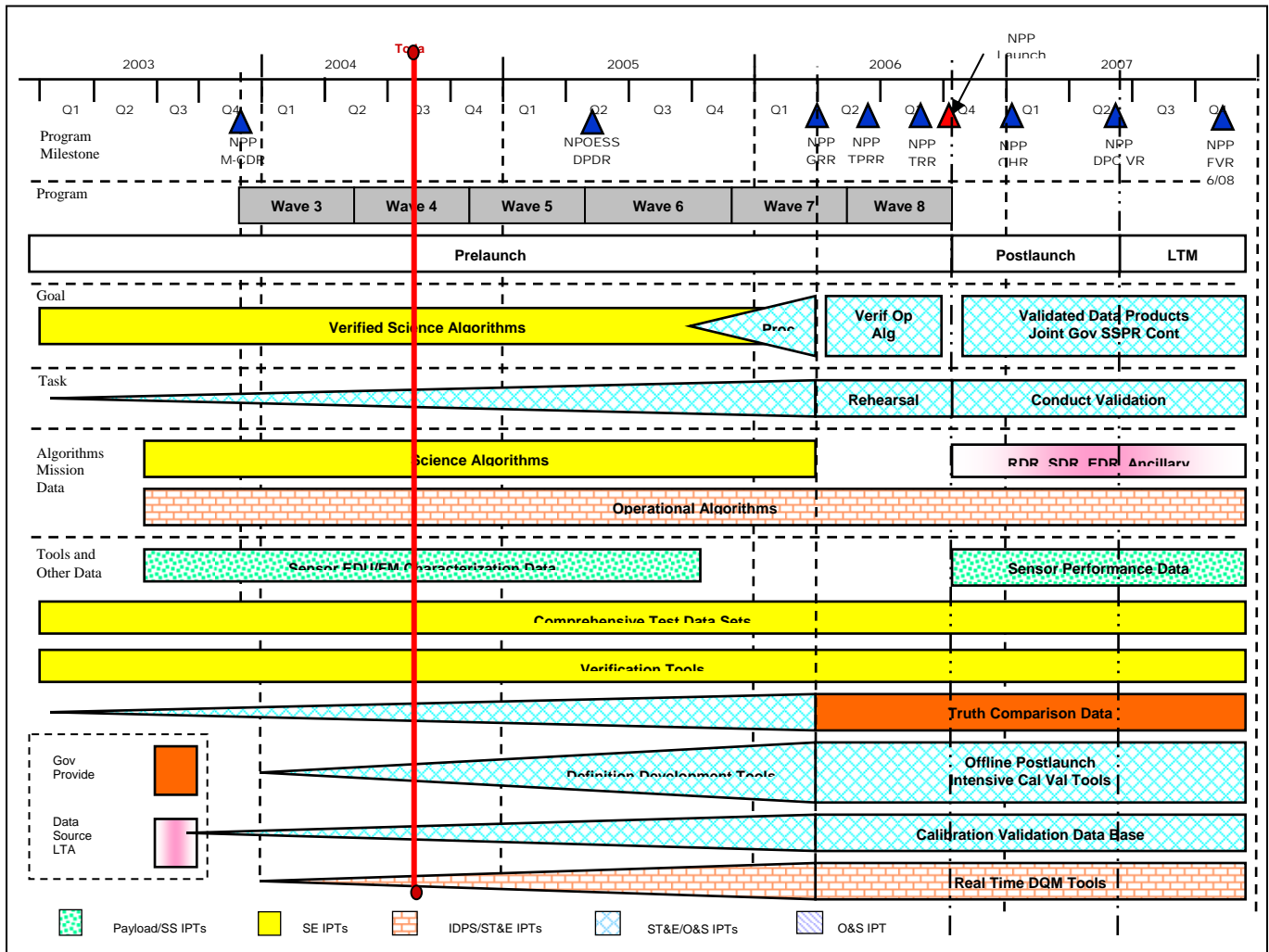


Figure 5 – NPP Cal Val Program Roadmap

For post-launch activities, the sensor specific Cal Val plans and the NPOESS Cal Val Working Group have served to help define the required validation tasks and necessary comparison truth resources. Validation tasks and comparison data are documented in the Joint Government SSPR contractor NPP Cal Val Plan. The NPOESS Cal Val Working Group will continue to develop the details through NPP GRR, and will coordinate several validation rehearsals in the 2006 timeframe. The SSPR contractor is in the process of identifying and developing plans to acquire or leverage the necessary tools to conduct SDR and EDR validation. Algorithm verification tools already in use pre-launch will be re-exercised post launch upon update of the sensor models.

For the long term monitoring phase, the Data Quality Monitoring (DQM) Sub System is under development by the IDPS IPT. Basic functionality has been demonstrated, and design implementation for the bulk of the functions is underway. This system will provide a look at the first few hours of the life of the NPOESS data, and perform longer term trending of sensor parameters and environmental data records.

To support all phases of the Cal Val program, the SSPR contractor Cal Val team is developing a Calibration Validation Data Base to store and make available necessary data and tools for the NPOESS Cal Val Program. The NOAA NESDIS Comprehensive Large Array-Data Steward System (CLASS) will serve as the primarily source for NPOESS mission data needed for Cal Val. The government will provide the truth comparison resources. A ground segment maintenance facility will serve as the primarily processing resource for Cal Val tasks that require intensive computational effort or require handling of significant volumes of data. These activities will fully mature by NPP GRR.

## **5. SUMMARY**

The NPOESS Cal Val program has been underway for over five years, with a combined SSPR contractor Government intensive effort since SSPR contract award, August 2002. The primary objective of the NPOESS Cal Val program is to ensure the environmental data products meet the Appendix D system specification and satisfy the users. A cooperative strategy is in place that includes both government and SSPR contractor participants, in performer and related advisory roles. A Joint Government SSPR Contractor NPOESS Cal Val Working Group has been established and is chartered to coordinate the planning and support the execution of the Cal Val program. Activities to date include a leadership plenary, focused efforts on pre-launch sensor characterization and calibration, and initial work on post launch SDR/EDR validation. Technical interchange meetings were also conducted with the four NPOESS centrals (NESDIS, FNMOC, AFWA, and NAVO). The SSPR contractor approach leverages expertise across the program to conduct Cal Val activities within their normal scope of work. A SSPR contractor Cal Val team is in place to serve as the corporate memory, enhance pre-launch activities, and conduct post launch and long term monitoring activities. A series of Cal Val plans are under development and help guide the NPOESS Cal Val program. A Joint Government SSPR contractor team is in place and is developing the Joint NPP Cal Val Plan. A roadmap to NPP is established and the cooperative team is supporting those activities.



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